

## PATENT ABSTRACTS OF JAPAN

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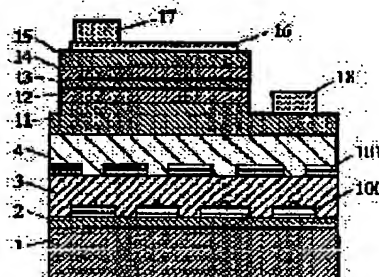
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## (54) NITRIDE SEMICONDUCTOR LIGHT-RECEIVING ELEMENT

## (57)Abstract:

**PROBLEM TO BE SOLVED:** To realize a laser element of a structure, wherein light which leaks mainly in the side of a substrate is effectively made to reflect to improve the light extraction efficiency of a light-emitting element and at the same time, effective reflecting mirrors, which are used as resonators, are provided in the interior of a semiconductor layer.

**SOLUTION:** First, reflecting mirrors 100, which are not grown with a nitride semiconductor film on the surfaces thereof or have a property to hardly grow the nitride semiconductor film on the surfaces thereof and make light emission from an active layer reflect, are partially formed on a base layer consisting of a first nitride semiconductor layer 2 formed on a substrate 1, consisting of a material different from a nitride semiconductor material. Moreover, a second nitride semiconductor layer 3 grown in such a way that the layer 3 reaches from the window parts of the mirrors 100 to the surface of the mirrors 100 is used as a substrate, and a plurality of nitride semiconductor layers including at least the active layer are laminated on the substrate, whereby the light emission from the active layer is made to be reflected upwards by the mirrors 100.



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**CLAIMS**


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**[Claim(s)]**

[Claim 1] On the ground layer which consists of the 1st nitride semiconductor formed on the different-species substrate which consists of a different material from a nitride semiconductor Or it has the property to be hard to grow up. or [ that a nitride semiconductor does not grow up to be a front face ] — And the 1st reflecting mirror which reflects luminescence of a barrier layer is formed partially, and the 2nd nitride semiconductor which grew so that the front face of the reflecting mirror might be reached is further used as a substrate from the window part of the 1st reflecting mirror. The nitride semiconductor light emitting device to which the laminating of two or more nitride semiconductor layers which contain a barrier layer at least on the substrate is carried out, and they are characterized by the bird clapper.

[Claim 2] The nitride semiconductor light emitting device according to claim 1 which the 2nd reflecting mirror is partially formed on the nitride semiconductor layer of the above 2nd, and two or more nitride semiconductor layers which contain a barrier layer at least on the substrate grow by using as a substrate the 3rd nitride semiconductor which grew from the window part of the 2nd reflecting mirror so that the front face of the 2nd reflecting mirror might be reached, and is characterized by the bird clapper.

[Claim 3] The 2nd reflecting mirror of the above is a nitride semiconductor light emitting device according to claim 2 characterized by being formed on the 2nd nitride semiconductor layer corresponding to the position of the window part of the 1st reflecting mirror.

[Claim 4] The nitride semiconductor light emitting device according to claim 1 to which area of the aforementioned reflecting mirror is characterized by being larger than the area of a window part.

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## DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] this invention relates to the light emitting device which consists of a nitride semiconductor ( $\text{In}_a\text{Al}_b\text{Ga}_{1-a-b}\text{N}$ ,  $0 \leq a$ ,  $0 \leq b$ ,  $a+b \leq 1$ ) used for light emitting diode (Light Emitting Diode), a laser diode (LD), a super luminescent diode (SLD), etc.

[0002]

[Description of the Prior Art] The nitride semiconductor is already put in practical use as blue Light Emitting Diode and a green Light Emitting Diode. These Light Emitting Diodes have a structure to the double by which the laminating of an n type and the p type nitride semiconductor was carried out on silicon on sapphire, and the barrier layer has the nitride semiconductor layer of quantum well structure. The nitride semiconductor light emitting device which constitutes Light Emitting Diode is divided into two kinds of modes, the case where this silicon-on-sapphire side is made into a luminescence observation side, and when a nitride semiconductor layer side is made into a luminescence observation side. Since the chip size became large, and it generally uses the property of transparent sapphire positively although handling nature also has the fault which becomes bad in case an electrode is connected to a base material like a leadframe since positive and the negative electrode are prepared in the same side when a nitride semiconductor makes a silicon-on-sapphire side a luminescence observation side for example, there is an advantage that optical ejection efficiency becomes good. On the other hand, although a chip size can also be made small and handling nature is also very excellent compared with the case of the former when making a nitride semiconductor side into a luminescence observation side, the light which leaks to a silicon-on-sapphire side has the fault that it is absorbed by the adhesives of a leadframe and optical ejection efficiency becomes bad. The direction of the latter with handling nature sufficient [Light Emitting Diode generally marketed] is chosen.

[0003]

[Problem(s) to be Solved by the Invention] Although the technology which forms a light reflex film in a silicon-on-sapphire front face was also proposed in order to reflect the light which leaks to a silicon-on-sapphire side in the case of the latter, it was not what it can still be satisfied [with this technology] of enough. Moreover, in the technology which forms a reflecting mirror in the interior of a semiconductor layer like a surface emission-type laser element, when a reflecting mirror is provided in a silicon-on-sapphire side, it is in a difficult inclination that distance with a barrier layer is too large, and uses a reflecting mirror as a resonator.

[0004] It is in realizing the laser element which has the effective reflecting mirror which this invention is made in view of such a situation, and the place made into the purpose makes reflect effectively the light which leaks mainly to a substrate side, and is to raise the optical ejection efficiency of a light emitting device, and serves as a resonator inside a semiconductor layer.

[0005]

[Means for Solving the Problem] The light emitting device of this invention on the ground layer which consists of the 1st nitride semiconductor formed on the different-species substrate which consists of a different material from a nitride semiconductor. Or it has the property to be hard to grow up, or [that a nitride semiconductor does not grow up to be a front face] — And the 1st reflecting mirror which reflects luminescence of a barrier layer is formed partially, and the 2nd nitride semiconductor which grew so that the front face of the reflecting mirror might be reached is further used as a substrate from the window part of the 1st reflecting mirror. The laminating of two or more nitride semiconductor layers which contain a barrier layer at least on the substrate is carried out, and they are characterized by the bird clapper.

[0006] Furthermore, the 2nd reflecting mirror is partially formed on the nitride semiconductor layer of the above 2nd, from the window part of the 2nd reflecting mirror, by using as a substrate the 3rd nitride semiconductor which grew so that the front face of the 2nd reflecting mirror might be reached, two or more nitride semiconductor layers which contain a barrier layer at least on the substrate grow, and the light emitting device of this invention is characterized by the bird clapper.

[0007] As for the 2nd reflecting mirror of the above, it is desirable to be formed on the 2nd nitride semiconductor layer corresponding to the position of the window part of the 1st reflecting mirror. In addition, in this invention, you may grow up the semiconductor layer which consists of material which a different-species substrate, the 1st reflecting mirror, a ground layer, the nitride semiconductor layer containing the barrier layer above the 2nd nitride semiconductor, and the 2nd nitride semiconductor touch, and do not necessarily need to be formed, for example, is different from a nitride semiconductor among them.

[0008] Moreover, in the light emitting device of this invention, at least one of the aforementioned reflecting mirror is characterized by being larger than the area of a window part.

[0009]

[Embodiments of the Invention] Drawing 1 is the typical cross section showing the structure of the nitride semiconductor wafer obtained in each process until it grows up the 2nd nitride semiconductor layer from a different-species substrate in the light emitting device of this invention.

[0010] In order to grow up the substrate which consists of the 2nd nitride semiconductor 3, as first shown in drawing 1 (a), on the different-species substrate 1, the ground layer 2 which consists of the 1st nitride semiconductor is grown up, and

the 1st reflecting mirror 100 is partially formed on the ground layer 2. The different-species substrate 1 consists of a different material from the nitride semiconductor proposed conventionally, and the material with which a nitride semiconductor can grow up to be the front face through a buffer layer is chosen. The oxide system substrate which carries out grid adjustment also in it with a spin 1 (MgAl<sub>2</sub>O<sub>4</sub>) besides the sapphire put in practical use, ZnO, GaAs, Si and SiC, and a nitride semiconductor is proposed.

[0011] The ground layer 2 can grow in 200 degrees C - 900 degrees C low temperature through the buffer layer which consists of AlXGa1-XN (0<X<=1) by growing up a nitride semiconductor at an elevated temperature rather than the buffer layer. In this invention, it is called a ground layer including a nitride semiconductor including the buffer layer. That is, the ground layer may consist of two or more nitride semiconductor layers. However, in order that a ground layer may grow on a different-species substrate, according to factors, such as a coefficient-of-thermal-expansion difference of a different-species substrate and a ground layer, and grid mismatching, it has very many crystal defects, for example, has 10<sup>9</sup> more than [ /cm / 2 ] penetration transposition, and does not serve as a nitride semiconductor substrate. As most desirable ground layer, undoping or n type high impurity concentration grows up three or less 1x10<sup>17</sup> /cm GaN through a buffer layer. In addition, the buffer layer which consists of nitride semiconductors, such as ZnO, and a different semiconductor between a ground layer and a different-species substrate can also be grown up.

[0012] The 1st reflecting mirror 100 formed on the ground layer 2 has the operation which lessens the crystal defect of the 2nd nitride semiconductor layer which grows up to be a longitudinal direction so that the front face of a reflecting mirror may be reached [ from the window part of a reflecting mirror ] while having the operation which reflects luminescence of a barrier layer in the upper part. A reflecting mirror is preferably formed in the shape of a stripe, although what configuration is sufficient as long as it forms partially on a shape of shape for example, of stripe, and dot, in-a-grid-pattern \*\*, and ground layer. or [ that a nitride semiconductor does not grow up to be the front face of the reflecting mirror as a material of a reflecting mirror ] — or if it is the material which has the property to be hard to grow up and is the material which reflects luminescence of a barrier layer in a barrier-layer side, the multilayer which what material is sufficient as, for example, consists of the dielectric of SiO<sub>2</sub>, Si<sub>3</sub>N<sub>4</sub>, TiO<sub>2</sub>, Ti<sub>3</sub>N<sub>4</sub>, and ZrO<sub>2</sub> grade can be chosen. It acts as a reflecting mirror by carrying out the laminating of these dielectrics so that it may be set to  $\lambda/4n$  ( $\lambda$ :luminescence wavelength, refractive index of n:dielectric). Moreover, the metal which has the property in which luminescence of a barrier layer is reflected with the metal of silver white, and a nitride semiconductor cannot grow up to be a front face easily like Pt, nickel, Cr, and Ag is sufficient. In addition, as for a reflecting mirror, it is desirable to choose the material which has the melting point to which a dielectric multilayer, a metal, etc. bear the growth temperature of the 2nd nitride semiconductor.

[0013] Although the 1st reflecting mirror 100 is formed on the ground layer which consists of the 1st nitride semiconductor which grows on the different-species substrate 1 as shown in drawing 1, it can also be directly formed on the different-species substrate 1. For example, when sapphire is used for the different-species substrate 1, it is desirable to grow up the 1st nitride semiconductor 2 on sapphire when growing up the 2nd nitride semiconductor 3 with more few crystal defects. On the other hand, when using for a substrate the substrate which carried out grid adjustment with the nitride semiconductor, and a substrate with a near lattice constant, it is also possible to form the 1st reflecting mirror 100 in contact with a different-species substrate directly.

[0014] Next, as shown in drawing 1 (b), the 2nd nitride semiconductor 3 is grown up from the window part of the ground layer in which the aforementioned reflecting mirror was formed. Since the reflecting mirror 100 has the property in which a nitride semiconductor cannot grow up to be a front face easily, as the 2nd nitride semiconductor 3 grows from a window part and is shown in a broth and (b), it grows up to be a longitudinal direction in the upper part of the 1st reflecting mirror 100. If growth is furthermore continued, as shown in drawing 1 (c), the 2nd nitride semiconductor which grows up to be a longitudinal direction and lengthwise will be about connected in the upper part of a reflecting mirror center section, and will serve as a nitride semiconductor substrate. When the 2nd nitride semiconductor 3 is grown up, the crystal defect of the 2nd nitride semiconductor which grows up to be a longitudinal direction stops thus, extending from a ground layer by covering the crystal defect of the ground layer 2 with the reflecting mirror. Moreover, as the crystal defect extended from a window part is the 2nd nitride semiconductor layer, in order to stop, after the 2nd nitride semiconductor layer growth, the crystal defect which appears in a front face decreases very much, for example, becomes 2 or less [ 10<sup>8</sup> //cm ] and 2 or less [ 10<sup>7</sup> more //cm ]. The 2nd nitride semiconductor 3 is the most desirable when it produces a crystalline good substrate that undoping or n type high impurity concentration grows up three or less 1x10<sup>17</sup> /cm GaN.

[0015] As a still more desirable mode, as shown in drawing 1 (d), the 2nd reflecting mirror 101 as well as [ still ] the 1st reflecting mirror is formed on the 2nd nitride semiconductor layer, and the 3rd nitride semiconductor layer 4 is similarly grown up into the upper part of this 2nd reflecting mirror 101. By forming the 2nd reflecting mirror 101, the crystal defect of the 3rd nitride semiconductor 4 grown up into the upper part of the 2nd reflecting mirror decreases further. That is, because there are few crystal defects of the 2nd nitride semiconductor layer 3 used as a ground. As preferably shown in (d), it serves superficially from a nitride semiconductor layer side by forming the position of the 2nd reflecting mirror 101 in the front face of the 2nd nitride semiconductor layer 3 corresponding to the window part of the 1st reflecting mirror, and since it becomes the form where all were covered with the reflecting mirror, optical ejection efficiency improves further. Moreover, when the crystal defect of the 2nd nitride semiconductor 3 has appeared in the window part, for example, for a wrap reason, the crystal defect of the 3rd nitride semiconductor layer which grows up to be a longitudinal direction on the 2nd reflecting mirror decreases the window part further with the 2nd reflecting mirror. That is, as for the 2nd reflecting mirror 101, it is most desirable to form on the 1st nitride semiconductor layer 3 to which the crystal defect has appeared in the front face. However, you may form the 3rd reflecting mirror at random.

[0016] The operation of the reflecting mirror of this invention is as follows. The nitride semiconductor layer which grows from the window part of a reflecting mirror and grows up to be a longitudinal direction on the surface of the reflecting mirror has very few crystal defects. Therefore, the crystal defect of the nitride semiconductor layer containing the barrier layer grown up on the substrate decreases like a nitride semiconductor substrate by using the nitride semiconductor as a substrate. Therefore, an element becomes long lasting, in order that a crystal defect may not carry out transposition to a barrier layer, when a light emitting device is produced. Moreover, it improves in all fields, such as pressure-proofing of an opposite direction, and the current characteristic of a leakage current. And for a certain reason, the light of the

operation which reflects luminescence of a barrier layer in a barrier-layer side which leaks to a substrate side decreases, and optical junction efficiency of a reflecting mirror improves in the light emitting device which makes a semiconductor side a luminescence observation side. Therefore, while the reflection efficiency becomes large and optical ejection efficiency improves by making area of a reflecting mirror larger than that of a window part, the number of the crystal defects extended from a window part also decreases, and a still more desirable light emitting device can be realized. As stated also in advance preferably, since it becomes the form where the reflecting mirror was wearing all the fields substantially on the flat surface, by arranging a reflecting mirror in two or more stages lengthwise, optical ejection efficiency improves further. Moreover, in the case of a laser element, since it acts as a resonator, a surface emission-type laser element is realizable [the 1st reflecting mirror 100 or the 2nd reflecting mirror 101 is in the interior of a semiconductor layer, distance of which with a barrier layer is near, and] with a nitride semiconductor.

[0017]

[Example] [Example 1] drawing 2 is the type section view showing the structure of the Light Emitting Diode element concerning an example 1. Based on this drawing, an example 1 is explained below. First, the MOVPE method is used on the different-species substrate 1 which consists of sapphire, and the 1st nitride semiconductor layer 2 is grown up. The 1st nitride semiconductor layer 2 consists of a buffer layer which consists of GaN which grew at 500 degrees C sequentially from a different-species substrate side, and GaN which grew at 1050 degrees C on the buffer layer.

[0018] Next, by the CVD system, all over the 1st nitride semiconductor layer 2, a wafer is picked out from a reaction container, and two or more dielectric multilayers which consist of SiO<sub>2</sub> and SiN are formed by turns so that single thickness may be set to  $\lambda/4n$ , and a dielectric multilayer is formed.

[0019] A mask is formed in the position on the dielectric multilayer after dielectric multilayer formation, selective etching of the dielectric multilayer is carried out, and it considers as stripe width of face of 10 micrometers, and the stripe interval (window part) of 2 micrometers, and considers as the 1st reflecting mirror 100. In case such 1st reflecting mirror 100 is formed by the dielectric multilayer, form a dielectric multilayer all over the 1st nitride semiconductor layer first, and selective etching of the dielectric multilayer is carried out after that. The technology made into a predetermined configuration forms a mask in the position on a nitride semiconductor layer, forms a dielectric multilayer from on the, and a dielectric multilayer tends to form it by uniform thickness compared with the method of removing a mask and leaving only a dielectric multilayer by the lift-off method after that. Moreover, since it \*\*\*\*\*s, the nitride semiconductor layer front face of a window part also tends to observe an etch pit, a crystal defect, etc. which have appeared in the front face. The same of the advantage of this technique is said of the case of the 2nd reflecting mirror 101.

[0020] Next, after forming the 1st reflecting mirror 100, a wafer is returned in a MOVPE reaction container and the 2nd nitride semiconductor layer 3 which consists of undoping GaN at 1050 degrees C is grown up by 20-micrometer thickness.

[0021] A wafer is picked out from a reaction container after the 2nd nitride semiconductor layer 3 growth, and after forming again the dielectric multilayer which consists of SiO<sub>2</sub> and SiN all over the 2nd nitride semiconductor layer 3 in a CVD system, from selective etching, it considers as stripe width of face of 10 micrometers, and 2 micrometers of window parts, and considers as the 2nd reflecting mirror 102. However, it forms so that the stripe of the 1st reflecting mirror 100 and the 2nd reflecting mirror 101 may become parallel, and it sees from a flat surface, and is made for the window part of the 1st reflecting mirror 100 to be closed as the formation position of the 2nd reflecting mirror 101 is shown in drawing 2.

[0022] Next, a wafer is returned in a reaction container and the 3rd nitride semiconductor layer 4 which consists of undoping GaN at 1050 degrees C is grown up by 20-micrometer thickness.

[0023] Then, 4 micrometers of the n side contact layers 11 which consist of n type GaN which carried out Si dope at 1050 degrees C are grown up, and 0.1 micrometers of the n side clad layers 12 to which Si concentration consists of GaN fewer than the n side contact layer on it are grown up.

[0024] Next, the barrier layer 13 which consists of undoping In<sub>0.1</sub>Ga<sub>0.9</sub>N which has the single quantum well structure of 30Å of thickness at 800 degrees C is grown up, 0.1 micrometers of the p side clad layers 14 which consist of Mg dope p type aluminum<sub>0.1</sub>Ga<sub>0.9</sub>N at 1050 degrees C on it are grown up, and 0.5 micrometers of the p side contact layers 15 which become the last from Mg dope p type GaN are grown up.

[0025] After picking out a wafer from a reaction container after a reaction end, performing annealing at 700 degrees C among nitrogen-gas-atmosphere and forming p type layer into low resistance further, as shown in drawing 2, etching is performed from the p side contact layer 15 side, and the front face of the n side contact layer 11 is exposed. then, the front face of the p side contact layer of the best layer — almost — the whole surface — ohmic one of a translucency — the p electrode 16 of business is formed and p pad electrode 17 for bondings is formed on it. On the other hand, the n electrode 18 which consists of W/aluminum is formed in the front face of the n side contact layer 18 in which the point was exposed.

[0026] After grinding silicon on sapphire and making it thin finally, when it separated into the chip of 350-micrometer angle and considered as the blue Light Emitting Diode element, as compared with the conventional Light Emitting Diode element which does not prepare a reflecting mirror, it improved 50% or more with the output, and improved several or more times from the element life. Moreover, pressure-proofing of an opposite direction also improved 50% or more as compared with the conventional thing. Since the 2nd and 3rd nitride semiconductor serves as a substrate, the crystal defect of this of the element itself decreases and it can be imagined to be that pressure-proofing of an opposite direction and whose element life improved.

[0027] [Example 2] drawing 3 is the type section view showing the structure of LD element concerning the example 2 of this invention, and specifically shows the structure of a surface emission-type laser element. Based on this drawing, an example 2 is explained below.

[0028] The laminating of the 2nd reflecting mirror 101 of the shape of a stripe which consists of a GaN buffer layer, the 1st nitride semiconductor layer 2 which consists of undoping GaN, the 1st reflecting mirror 100 of the shape of a stripe which consists of a dielectric multilayer, the 2nd nitride semiconductor layer 3 which consists of undoping GaN, and a dielectric multilayer like an example 1 on the different-species substrate 1 which consists of sapphire, and the 3rd nitride semiconductor layer 4 which consists of undoping GaN is carried out to order.

[0029] Then, after growing up 4 micrometers of the n side contact layers 21 which consist of Si dope n type GaN, the

laminating the undoping aluminum $0.15\text{Ga}0.85\text{N}$  layer and the Si-doped GaN layer of  $25\text{\AA}$  of thickness of  $25\text{\AA}$  of thickness is carried out by turns, and the n-side clad layer 22 which consists of the superlattice of the  $0.4$  micrometers of the total thickness is grown up.

[0030] Next, the laminating of the well layer which consists of the barrier layer and  $40\text{\AA}$  undoping  $\text{In}0.2\text{Ga}0.8\text{N}$  which consists of  $40\text{\AA}$  undoping  $\text{In}0.01\text{Ga}0.95\text{N}$  is carried out by turns, finally it is finished as a barrier layer, and the barrier layer 23 of the multiplex quantum well structure (MQW) of the  $440\text{\AA}$  of the total thickness is grown up.

[0031] Next, the laminating of  $25\text{\AA}$  undoping aluminum $0.15\text{Ga}0.85\text{N}$  layer and a  $25\text{\AA}$  Mg-doped GaN layer is carried out by turns, and the p-side clad layer 24 which consists of a superlattice layer of the  $0.4$  micrometers of the total thickness is grown up.

[0032] A wafer is picked out from a reaction container after the p-side clad layer growth, and the protective coat which consists of  $\text{SiO}_2$  which has a round shape is formed in the front face of the p-type clad layer. However, the position of the mask is smaller than the 2nd reflecting mirror 101 of the above, and it is formed so that it may become right above the reflecting mirror.

[0033] After protective coat formation, again, a wafer is moved in a reaction container and the current blocking layer 26 which consists of Si-doped n-type aluminum $0.1\text{Ga}0.9\text{N}$  is formed in the front face of the p-side clad layer 24 in which the protective coat is not formed by  $0.4$ -micrometer thickness. In addition, p-type impurity which cannot become p-type easily even if this current blocking layer dopes a p-type impurity like Zn and Cd — doping — high — good also as an i-type nitride semiconductor layer [\*\*\*\*] — carrying out — moreover, aluminum mixed-crystal ratio — a clad layer — large — carrying out — high — i-type  $\text{AlGaIn}$  [\*\*\*\*] can also be formed.

[0034] After picking out a wafer from a reaction container after current blocking-layer 26 formation and carrying out dissolution removal of the protective coat, the p-side contact layer 25 which consists of Mg-doped p-type GaN on the current blocking layer 26 in a reaction container again is grown up.

[0035] After a reaction end, annealing is performed and p-layers are further formed into low resistance, as well as an example 1. While forming the n-electrode 28 in the n-side contact layer 22 which was made to expose a part of n-side contact layer 22 by etching, and was exposed. After forming the p-electrode 27 in the front face of the p-side contact layer, when it is considered as the laser element of structure as divided a wafer into a chip and shown in drawing 3, continuous oscillation was shown in the room temperature and the  $410\text{nm}$  laser beam was observed from the silicon-on-sapphire side.

[0036] [Example 3] drawing 4 is the type section view showing the structure of LD element concerning the example 3 of this invention, and this also shows the structure of a surface emission-type laser element. Based on this drawing, an example 3 is explained below.

[0037] In an example 1, in case the 2nd nitride semiconductor layer 3 is grown up after forming the 1st reflecting mirror 100 of the shape of a stripe which consists of a GaN buffer layer, the 1st nitride semiconductor layer 2 which consists of undoping GaN, and a dielectric multilayer on the different-species substrate 1 which consists of sapphire, GaN which doped Si  $5 \times 10^{16} \text{--}/\text{cm}^3$  is grown up by  $60$ -micrometer thickness. Thickness of this 2nd nitride semiconductor layer is set to  $60$  micrometers or more for removing a different-species substrate behind and using the 2nd nitride semiconductor layer as a substrate. When thinner than  $60$  micrometers, the 2nd nitride semiconductor layer breaks during different-species substrate removal, and it is in the inclination for element production to become difficult. Furthermore, the little dope of the n-type impurity is carried out because the 2nd nitride semiconductor layer 3 and the very thing which are exposed are used as a contact layer after removing a different-species substrate. When doping n-type impurity in the 2nd nitride semiconductor layer and the 3rd nitride semiconductor layer which furthermore serve as a substrate, it is desirable to be referred to as three or less  $1 \times 10^{17} \text{--}/\text{cm}^3$  as stated also in advance. It is the shell which the number of the crystal defects in a nitride semiconductor layer will increase if it is made [more] than it, and cannot serve as a crystalline good substrate easily.

[0038] The 2nd reflecting mirror 101 is formed like an example 1 after the 2nd nitride semiconductor layer 3 growth.  $15$  micrometers of 3rd nitride semiconductor layer 4 which consists of undoping GaN are grown up after the 2nd reflecting mirror formation.

[0039] Next, the crack prevention layer 20 which consists of  $\text{In}0.05\text{Ga}0.95\text{N}$  which doped Si is grown up by  $0.15$ -micrometer thickness. By using the crack prevention layer 20 as the nitride semiconductor containing In, a crack stops easily being able to go into the nitride semiconductor layer containing aluminum which this layer grows up behind by becoming a buffer coat. In addition, this crack prevention layer cannot be overemphasized by that you may put into the laser element of an example 2.

[0040] The rest carries out the laminating of the n-side clad layer 22 which consists of a superlattice, the barrier layer 23 of MQW, the p-side clad layer 24 which consists of a superlattice, the current blocking layer 26, and the p-side contact layer 25 like an example 2.

[0041] After a reaction end, after performing annealing and forming p-layers into low resistance further, it grinds from a sapphire side and the different-species substrate 1, the 1st nitride semiconductor layer 2, and the 1st reflecting mirror 101 are removed. Then, after preparing ring-like n-electrode in the front face of the 2nd exposed nitride semiconductor layer 2, the wafer was separated in the shape of a chip, when considered as the laser element of structure as shown in drawing 4, continuous oscillation was shown in the room temperature and, similarly the  $410\text{nm}$  laser beam was observed from the 2nd nitride semiconductor layer 3 side. In addition, in case the n-electrode 28 is formed, in order to improve the ohmic contact of the electrode contact surface, technology, such as ion implantation, may be used and n-type impurity may be doped on the front face of the 2nd nitride semiconductor layer at high concentration.

[0042]

[Effect of the Invention] By the light emitting device of this invention, as explained above, since the crystal defect of a nitride semiconductor layer which grew from the window part of a reflecting mirror and grew up to be a longitudinal direction on the surface of the reflecting mirror decreases very much, the crystal defect of two or more nitride semiconductor layers containing the barrier layer grown up on the substrate decreases, and the reliability of an element improves. Moreover, since a reflecting mirror reflects luminance of a barrier layer in a barrier-layer side in a narrow distance of dozens of micrometers or less, the optical ejection efficiency of a light emitting device improves. Therefore, if this reflecting mirror is used positively, a surface emission-type laser element is realizable.

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]

[Drawing 1] The type section view showing partially the structure of the wafer for explaining each process at the time of manufacturing the light emitting device of this invention, respectively.

[Drawing 2] The type section view showing the structure of the light emitting device of an example 1.

[Drawing 3] The type section view showing the structure of the light emitting device of an example 2.

[Drawing 4] The type section view showing the structure of the light emitting device of an example 3.

[Description of Notations]

- 1 ... Different-species substrate
- 2 ... 1st nitride semiconductor layer
- 3 ... 2nd nitride semiconductor layer
- 4 ... 3rd nitride semiconductor layer
- 11 21 ... The n side contact layer
- 12 22 ... The n side clad layer
- 13 23 ... Barrier layer
- 14 24 ... The p side clad layer
- 15 25 ... The p side contact layer
- 20 ... Crack prevention layer
- 26 ... Current blocking layer
- 16 27 ... p electrode
- 17 ... p pad electrode
- 18 28 ... n electrode
- 100 ... The 1st reflecting mirror
- 101 ... The 2nd reflecting mirror

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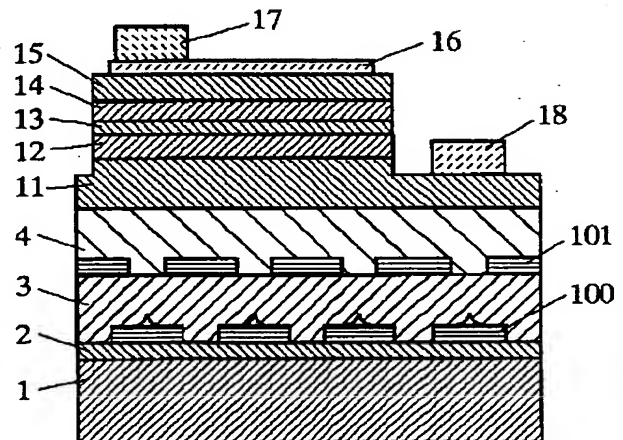
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(54)【発明の名称】窒化物半導体発光素子

(57)【要約】

【目的】 主として基板側に漏れる光を有効に反射させて、発光素子の光取り出し効率を向上させることにあり、また半導体層内部に共振器となる有効な反射鏡を有するレーザ素子を実現することにある。

【構成】 窒化物半導体と異なる材料よりなる異種基板上に形成された第1の窒化物半導体よりなる下地層の上に、表面に窒化物半導体が成長しないか若しくは成長しにくい性質を有し、かつ活性層の発光を反射する第1の反射鏡が部分的に形成されており、さらにその第1の反射鏡の窓部から、その反射鏡の表面に至るように成長された第2の窒化物半導体を基板として、その基板の上に少なくとも活性層を含む複数の窒化物半導体層が積層されいることにより、第1の反射鏡で活性層の発光を上方に反射させる。



## 【特許請求の範囲】

【請求項 1】 窒化物半導体と異なる材料よりなる異種基板上に形成された第 1 の窒化物半導体よりなる下地層の上に、表面に窒化物半導体が成長しないか若しくは成長しにくい性質を有し、かつ活性層の発光を反射する第 1 の反射鏡が部分的に形成されており、さらにその第 1 の反射鏡の窓部から、その反射鏡の表面に至るように成長された第 2 の窒化物半導体を基板として、その基板の上に少なくとも活性層を含む複数の窒化物半導体層が積層されてなることを特徴とする窒化物半導体発光素子。

【請求項 2】 前記第 2 の窒化物半導体層の上に第 2 の反射鏡が部分的に形成され、その第 2 の反射鏡の窓部から、第 2 の反射鏡の表面に至るように成長された第 3 の窒化物半導体を基板として、その基板の上に少なくとも活性層を含む複数の窒化物半導体層が成長されてなることを特徴とする請求項 1 に記載の窒化物半導体発光素子。

【請求項 3】 前記第 2 の反射鏡は、第 1 の反射鏡の窓部の位置に対応した第 2 の窒化物半導体層の上に形成されていることを特徴とする請求項 2 に記載の窒化物半導体発光素子。

【請求項 4】 前記反射鏡の面積が、窓部の面積よりも大きいことを特徴とする請求項 1 に記載の窒化物半導体発光素子。

## 【発明の詳細な説明】

## 【0001】

【産業上の利用分野】 本発明は発光ダイオード (LED)、レーザダイオード (LD)、スーパーluminescentダイオード (SLD) 等を使用される窒化物半導体 ( $In_{1-a}Al_bGa_{1-a-b}N$ ,  $0 \leq a$ ,  $0 \leq b$ ,  $a+b \leq 1$ ) よりなる発光素子に関する。

## 【0002】

【従来の技術】 窒化物半導体は青色 LED、緑色 LED として既に実用化されている。これら LED はサファイア基板上に n 型、p 型の窒化物半導体が積層されたダブルヘテロ構造を有し、活性層は量子井戸構造の窒化物半導体層を有している。LED を構成する窒化物半導体発光素子は、このサファイア基板側を発光観測面側とする場合と、窒化物半導体層側を発光観測面側とする場合の 2 種類の態様に分けられる。一般に窒化物半導体は正と負の電極が同一面側に設けられているため、サファイア基板側を発光観測面とした場合、例えばリードフレームのような支持体に電極を接続する際に、チップサイズが大きくなり、ハンドリング性も悪くなる欠点があるが、透明なサファイアの性質を積極的に利用しているので、光取り出し効率が良くなるという利点がある。一方、窒化物半導体側を発光観測面とする場合、チップサイズも小さくすることができ、ハンドリング性も前者の場合に比べて非常に優れているが、サファイア基板側に漏れる光は、例えばリードフレームの接着剤に吸収されて光取

り出し効率が悪くなるという欠点がある。一般に市販されている LED は、ハンドリング性の良い後者の方が選択されている。

## 【0003】

【発明が解決しようとする課題】 後者の場合、サファイア基板側に漏れる光を反射させるために、サファイア基板表面に光反射膜を形成する技術も提案されているが、この技術では未だ十分満足できるものではなかった。また、面発光レーザ素子のような半導体層内部に反射鏡を形成する技術において、サファイア基板側に反射鏡を設けると活性層との距離が大きすぎて、反射鏡を共振器とするのが難しい傾向にある。

【0004】 本発明はこのような事情を鑑みてなされたものであって、その目的とするところは、主として基板側に漏れる光を有効に反射させて、発光素子の光取り出し効率を向上させることにあり、また半導体層内部に共振器となる有効な反射鏡を有するレーザ素子を実現することにある。

## 【0005】

【課題を解決するための手段】 本発明の発光素子は、窒化物半導体と異なる材料よりなる異種基板上に形成された第 1 の窒化物半導体よりなる下地層の上に、表面に窒化物半導体が成長しないか若しくは成長しにくい性質を有し、かつ活性層の発光を反射する第 1 の反射鏡が部分的に形成されており、さらにその第 1 の反射鏡の窓部から、その反射鏡の表面に至るように成長された第 2 の窒化物半導体を基板として、その基板の上に少なくとも活性層を含む複数の窒化物半導体層が積層されてなることを特徴とする。

【0006】 さらに、本発明の発光素子は、前記第 2 の窒化物半導体層の上に第 2 の反射鏡が部分的に形成され、その第 2 の反射鏡の窓部から、第 2 の反射鏡の表面に至るように成長された第 3 の窒化物半導体を基板として、その基板の上に少なくとも活性層を含む複数の窒化物半導体層が成長されてなることを特徴とする。

【0007】 前記第 2 の反射鏡は、第 1 の反射鏡の窓部の位置に対応した第 2 の窒化物半導体層の上に形成されていることが望ましい。なお、本発明において、異種基板、第 1 の反射鏡、下地層、第 2 の窒化物半導体より上の活性層を含む窒化物半導体層と第 2 の窒化物半導体とは必ずしも接して形成されている必要はなく、例えば窒化物半導体と異なる材料よりなる半導体層を、それらの間に成長させても良い。

【0008】 また本発明の発光素子では、前記反射鏡の面積が、窓部の面積よりも大きいことを特徴とする。

## 【0009】

【発明の実施の形態】 図 1 は、本発明の発光素子において、異種基板から第 2 の窒化物半導体層を成長させるまでの各工程において得られる窒化物半導体ウェーハの構造を示す模式的な断面図である。

【0010】第2の窒化物半導体3よりなる基板を成長させるには、まず図1(a)に示すように、異種基板1の上に第1の窒化物半導体よりなる下地層2を成長させ、その下地層2の上に第1の反射鏡100を部分的に形成する。異種基板1は従来より提案されている窒化物半導体と異なる材料よりなり、その表面に例えばバッファ層を介して窒化物半導体が成長できる材料が選択される。その中でも、実用化されているサファイアその他、スピネル(MgAl<sub>2</sub>O<sub>4</sub>)、ZnO、GaAs、Si、SiC、窒化物半導体と格子整合する酸化物系基板等が提案されている。

【0011】下地層2は、例えば200℃～900℃の低温において、Al<sub>x</sub>Ga<sub>1-x</sub>N (0 ≤ x ≤ 1)よりなるバッファ層を介して、そのバッファ層よりも高温で窒化物半導体を成長させることによって成長できる。本発明では、バッファ層を含めた窒化物半導体を含んで下地層という。つまり、下地層は複数の窒化物半導体層から成っていても良い。但し、下地層は異種基板の上に成長されるため、異種基板と下地層との熱膨張係数差、格子不整合等の要因により結晶欠陥が非常に多く、例えば貫通転位が10<sup>8</sup>個/cm<sup>2</sup>以上あり、窒化物半導体基板とならない。最も好ましい下地層としてはアンドープ若しくはn型不純物濃度が1×10<sup>17</sup>/cm<sup>3</sup>以下のGaNをバッファ層を介して成長させる。なお、下地層と異種基板との間に例えばZnO等の窒化物半導体と異なる半導体よりなるバッファ層を成長させることもできる。

【0012】下地層2の上に形成する第1の反射鏡100は、活性層の発光を上部に反射させる作用を有すると共に、反射鏡の窓部から反射鏡の表面に至るように横方向に成長する第2の窒化物半導体層の結晶欠陥を少なくする作用を有する。反射鏡は、例えばストライプ状、ドット状、碁盤目状等、下地層の上に部分的に形成すればどのような形状でも良いが、好ましくはストライプ状に形成する。反射鏡の材料としては、窒化物半導体とその反射鏡の表面に成長しないか若しくは成長しにくい性質を有する材料で、活性層の発光を活性層側に反射させる材料であれば、どのような材料でも良く、例えばSiO<sub>2</sub>、SixNy、TiO<sub>2</sub>、TixNy、ZrO<sub>2</sub>等の誘電体より成る多層膜が選択できる。これら誘電体を例えばλ/4n (λ:発光波長、n:誘電体の屈折率)となるように積層することにより反射鏡として作用する。またPt、Ni、Cr、Ag等のように、例えば銀白色の金属で活性層の発光を反射して、表面に窒化物半導体が成長しにくい性質を有する金属でもよい。なお、反射鏡は、誘電体多層膜、金属等が第2の窒化物半導体の成長温度に耐える融点を有している材料を選択することが望ましい。

【0013】第1の反射鏡100は図1に示すように異種基板1の上に成長した第1の窒化物半導体よりなる下地層の上に形成されているが、異種基板1の上に直接形

成することもできる。例えば異種基板1にサファイアを使用した場合には、サファイアの上に第1の窒化物半導体2を成長させることが、より結晶欠陥の少ない第2の窒化物半導体3を成長させる上で望ましい。一方、基板に窒化物半導体と格子整合した基板、格子定数の近い基板を用いる場合には、第1の反射鏡100を直接、異種基板に接して形成することも可能である。

【0014】次に図1(b)に示すように第2の窒化物半導体3を、前記反射鏡を形成した下地層の窓部から成長させる。反射鏡100は表面に窒化物半導体が成長しにくい性質を有しているため、第2の窒化物半導体3は窓部から成長しだし、(b)に示すように、第1の反射鏡100の上部では横方向に成長する。さらに成長を続けると、図1(c)に示すように、横方向及び縦方向に成長する第2の窒化物半導体がおおよそ反射鏡中央部の上部で繋がって、窒化物半導体基板となる。このように第2の窒化物半導体3を成長させると、下地層2の結晶欠陥が反射鏡で覆われていることにより、横方向に成長する第2の窒化物半導体の結晶欠陥は、下地層から伸びてこなくなる。また窓部から伸びてくる結晶欠陥が第2の窒化物半導体層の途中で止まるため、第2の窒化物半導体層成長後、表面に現れる結晶欠陥は非常に少なくなり、例えば10<sup>8</sup>個/cm<sup>2</sup>以下、さらには10<sup>7</sup>個/cm<sup>2</sup>以下になる。第2の窒化物半導体3は、アンドープ若しくはn型不純物濃度が1×10<sup>17</sup>/cm<sup>3</sup>以下のGaNを成長させることが結晶性の良い基板を作製する上で最も好ましい。

【0015】さらに好ましい態様として、図1(d)に示すように、第2の窒化物半導体層の上に、さらに第1の反射鏡と同様に第2の反射鏡101を形成し、この第2の反射鏡101の上部に、第3の窒化物半導体層4を同様にして成長させる。第2の反射鏡101を形成することにより、その第2の反射鏡の上部に成長させる第3の窒化物半導体4の結晶欠陥がさらに少なくなる。それは下地となる第2の窒化物半導体層3の結晶欠陥が少ないからである。好ましくは(d)に示すように、第2の反射鏡101の位置を、第1の反射鏡の窓部に対応した第2の窒化物半導体層3の表面に形成することにより、窒化物半導体層側から平面的に見て、全てが反射鏡で覆われた形となるため、光取り出し効率がさらに向上する。また例えば第2の窒化物半導体3の結晶欠陥が窓部に現れている場合には、その窓部を第2の反射鏡でさらに覆うため、第2の反射鏡の上に横方向に成長される第3の窒化物半導体層の結晶欠陥がさらに少なくなる。即ち第2の反射鏡101は結晶欠陥が表面に現れている第1の窒化物半導体層3の上に形成することが最も好ましい。但し、第3の反射鏡はランダムに形成してもよい。

【0016】本発明の反射鏡の作用は次の通りである。反射鏡の窓部から成長されて、反射鏡の表面で横方向に成長された窒化物半導体層は結晶欠陥が非常に少ない。

そのため、その窒化物半導体を基板とすることにより、その基板の上に成長させる活性層を含む複数の窒化物半導体層の結晶欠陥が窒化物半導体基板と同じように少なくなる。従って、発光素子を作製した際には、活性層に結晶欠陥が転位しないため、素子が長寿命となる。また逆方向の耐圧、リーク電流の電流特性等全ての面において向上する。しかも、反射鏡は活性層の発光を活性層側に反射させる作用もあるため、基板側に漏れる光が少なくなつて、半導体側を発光観測面とする発光素子では光取り出し効率が向上する。そのため、窓部の面積よりも反射鏡の面積を大きくすることにより、反射部が大きくなつて光取り出し効率が向上すると共に、窓部から伸びる結晶欠陥の数も少なくなり、さらに好ましい発光素子の実現できる。好ましくは先にも述べたように、反射鏡を縦方向に二段階以上に並べることにより、平面上では反射鏡が実質的に全ての面を覆った形となるため、光取り出し効率はさらに向上する。また、レーザ素子の場合には、第1の反射鏡100若しくは第2の反射鏡101が半導体層内部にあり、活性層との距離が近い一方の共振器として作用するため、窒化物半導体で面発光レーザ素子の実現できる。

#### 【0017】

【実施例】【実施例1】図2は実施例1に係るLED素子の構造を示す模式断面図である。以下この図を元に、実施例1を説明する。まず、サファイアよりなる異種基板1の上にMOVPE法を用いて、第1の窒化物半導体層2を成長させる。第1の窒化物半導体層2は異種基板側から順に、500℃で成長されたGaNよりなるバッファ層と、バッファ層の上に1050℃で成長されたGaNからなる。

【0018】次に反応容器からウェーハを取り出し、CVD装置により、第1の窒化物半導体層2の全面に、SiO<sub>2</sub>とSiNよりなる誘電体多層膜を単一膜厚がλ/4nとなるように、交互に複数形成し、誘電体多層膜を形成する。

【0019】誘電体多層膜形成後、その誘電体多層膜上の所定の位置にマスクを形成して、その誘電体多層膜を選択エッチングして、ストライプ幅10μm、ストライプ間隔（窓部）2μmとし、第1の反射鏡100とする。このような第1の反射鏡100を誘電体多層膜で形成する際、最初に第1の窒化物半導体層の全面に誘電体多層膜を形成し、その後誘電体多層膜を選択エッチングして、所定の形状とする技術は、窒化物半導体層上の所定の位置にマスクを形成して、その上から誘電体多層膜を形成して、その後リフトオフ法により、マスクを除去して誘電体多層膜のみを残す方法に比べて、均一な膜厚で誘電体多層膜が形成しやすい。また、窓部の窒化物半導体層表面もエッチングされるため、表面に現れているエッチビット、結晶欠陥等を観察しやすい。この手法の利点は、第2の反射鏡101の場合も同様である。

【0020】次に第1の反射鏡100を形成した後、ウェーハをMOVPE反応容器内に戻し、1050℃でアンドープGaNよりなる第2の窒化物半導体層3を20μmの膜厚で成長させる。

【0021】第2の窒化物半導体層3成長後、ウェーハを反応容器から取り出し、再度CVD装置にて、第2の窒化物半導体層3の全面にSiO<sub>2</sub>とSiNよりなる誘電体多層膜を形成した後、選択エッチングより、ストライプ幅10μm、窓部2μmとし、第2の反射鏡102とする。但し第2の反射鏡101の形成位置は、図2に示すように、第1の反射鏡100と第2の反射鏡101のストライプが平行になるように形成して、平面から見て、第1の反射鏡100の窓部が塞がるようにする。

【0022】次に、ウェーハを反応容器内に戻し、1050℃でアンドープGaNよりなる第3の窒化物半導体層4を20μmの膜厚で成長させる。

【0023】続いて、1050℃でSiドーパしたn型GaNよりなるn側コンタクト層11を4μm成長させ、その上にSi濃度がn側コンタクト層よりも少ないGaNよりなるn側クラッド層12を0.1μm成長させる。

【0024】次に800℃で、膜厚30オングストロームの単一量子井戸構造を有するアンドープIn<sub>0.1</sub>Ga<sub>0.9</sub>Nよりなる活性層13を成長させ、その上に1050℃でMgドーパp型Al<sub>0.1</sub>Ga<sub>0.9</sub>Nよりなるp側クラッド層14を0.1μm成長させ、最後に、Mgドーパp型GaNよりなるp側コンタクト層15を0.5μm成長させる。

【0025】反応終了後、ウェーハを反応容器から取り出し、窒素雰囲気中700℃でアニーリングを行い、p型層をさらに低抵抗化した後、図2に示すようにp側コンタクト層15側からエッチングを行い、n側コンタクト層11の表面を露出させる。その後、最上層のp側コンタクト層の表面のほぼ全面に透光性のオーミック用のp電極16を形成し、その上にボンディング用のpパッド電極17を形成する。一方、先ほど露出させたn側コンタクト層18の表面には、W/Alよりなるn電極18を形成する。

【0026】最後に、サファイア基板を研磨して薄くした後、350μm角のチップに分離して青色LED素子としたところ、反射鏡を設けない従来のLED素子と比較して、出力で50%以上向上し、素子寿命で数倍以上に向上した。また逆方向の耐圧も従来のものに比較して、50%以上向上した。これは第2、第3の窒化物半導体が基板となっているために、素子自体の結晶欠陥が少なくなり、逆方向の耐圧、素子寿命が向上したものと推察できる。

【0027】【実施例2】図3は本発明の実施例2に係るLD素子の構造を示す模式断面図であり、具体的には面発光レーザ素子の構造を示している。以下この図を元

に、実施例2を説明する。

【0028】実施例1と同様にして、サファイアよりなる異種基板1の上に、Ga<sub>0.15</sub>Nバッファ層、アンドープGa<sub>0.15</sub>Nよりなる第1の窒化物半導体層2、誘電体多層膜より成るストライプ状の第1の反射鏡100、アンドープGa<sub>0.15</sub>Nよりなる第2の窒化物半導体層3、誘電体多層膜より成るストライプ状の第2の反射鏡101、アンドープGa<sub>0.15</sub>Nよりなる第3の窒化物半導体層4を順に積層させる。

【0029】続いて、Siドープn型Ga<sub>0.15</sub>Nよりなるn側コンタクト層21を4μm成長させた後、膜厚250ÅのAl<sub>0.15</sub>Ga<sub>0.85</sub>N層と、膜厚250ÅのSiドープGa<sub>0.15</sub>N層とを交互に積層して、総膜厚0.4μmの超格子より成るn側クラッド層22を成長させる。

【0030】次に、400ÅのAl<sub>0.15</sub>Ga<sub>0.85</sub>N層と、400ÅのSiドープGa<sub>0.15</sub>N層とを交互に積層し、最後に障壁層で終わり、総膜厚440Åの多重量子井戸構造(MQW)の活性層23を成長させる。

【0031】次に、250ÅのAl<sub>0.15</sub>Ga<sub>0.85</sub>N層と、250ÅのMgドープGa<sub>0.15</sub>N層とを交互に積層して、総膜厚0.4μmの超格子層よりなるp側クラッド層24を成長させる。

【0032】p側クラッド層成長後、ウェーハを反応容器から取り出し、円形を有するSiO<sub>2</sub>よりなる保護膜をそのp型クラッド層の表面に形成する。但し、そのマスクの位置は前記第2の反射鏡101よりも小さく、その反射鏡の真上になるように形成する。

【0033】保護膜形成後、再度、ウェーハを反応容器内に移し、その保護膜が形成されていないp側クラッド層24の表面にSiドープn型Al<sub>0.15</sub>Ga<sub>0.85</sub>Nよりなる電流阻止層26を0.4μmの膜厚で形成する。なおこの電流阻止層はZn、Cdのようなp型不純物をドーピングしてもp型になりにくいp型不純物をドーピングして、高抵抗なi型の窒化物半導体層としてもよいし、またAl混晶比をクラッド層よりも大きくして高抵抗なi型AlGa<sub>0.15</sub>Nを形成することもできる。

【0034】電流阻止層26形成後、ウェーハを反応容器から取り出し、保護膜を溶解除去した後、再び反応容器内において、その電流阻止層26の上にMgドープp型Ga<sub>0.15</sub>Nよりなるp側コンタクト層25を成長させる。

【0035】反応終了後、アニーリングを行いp層をさらに低抵抗化し、実施例1と同じく、エッチングによりn側コンタクト層22の一部を露出させ、露出したn側コンタクト層22にn電極28を形成する一方、p側コンタクト層の表面にp電極27を形成した後、ウェーハをチップに分離して図3に示すような構造のレーザ素子としたところ、室温において連続発振を示し、410nm

のレーザ光がサファイア基板側から観測された。

【0036】[実施例3] 図4は本発明の実施例3に係るLD素子の構造を示す模式断面図であり、これもまた面発光レーザ素子の構造を示している。以下この図を元に、実施例3を説明する。

【0037】実施例1において、サファイアよりなる異種基板1の上に、Ga<sub>0.15</sub>Nバッファ層、アンドープGa<sub>0.15</sub>Nよりなる第1の窒化物半導体層2、誘電体多層膜より成るストライプ状の第1の反射鏡100を形成した後、第2の窒化物半導体層3を成長させる際に、Siを5×10<sup>16</sup>/cm<sup>3</sup>ドーピングしたGa<sub>0.15</sub>Nを60μmの膜厚で成長させる。この第2の窒化物半導体層の膜厚を60μm以上にするのは、後に異種基板を除去して、第2の窒化物半導体層を基板とするためである。60μmよりも薄いと、異種基板除去中に第2の窒化物半導体層が割れて、素子作製が難しくなる傾向にある。さらにn型不純物を少量ドーピングするのは、異種基板を除去した後、露出される第2の窒化物半導体層3、そのものをコンタクト層とするからである。さらに基板となる第2の窒化物半導体層、第3の窒化物半導体層にn型不純物をドーピングする場合、先にも述べたように1×10<sup>17</sup>/cm<sup>3</sup>以下とすることが望ましい。それよりも多くすると窒化物半導体層中の結晶欠陥の数が増えて、結晶性の良い基板となりにくいからである。

【0038】第2の窒化物半導体層3成長後、実施例1と同様にして、第2の反射鏡101を形成する。第2の反射鏡形成後、アンドープGa<sub>0.15</sub>Nよりなる第3の窒化物半導体層4を15μm成長させる。

【0039】次にSiをドーピングしたIn<sub>0.05</sub>Ga<sub>0.95</sub>Nより成るクラック防止層20を0.15μmの膜厚で成長させる。クラック防止層20はInを含む窒化物半導体とすることにより、この層が緩衝層となり、後に成長させるAlを含む窒化物半導体層にクラックが入りにくくなる。なお、このクラック防止層は実施例2のレーザ素子に入れても良いことは言うまでもない。

【0040】あとは実施例2と同様にして、超格子よりなるn側クラッド層22、MQWの活性層23、超格子よりなるp側クラッド層24、電流阻止層26、p側コンタクト層25を積層する。

【0041】反応終了後、アニーリングを行いp層をさらに低抵抗化した後、サファイア側から研磨して、異種基板1、第1の窒化物半導体層2、第1の反射鏡101を除去する。その後、露出させた第2の窒化物半導体層2の表面にリング状のn電極を設けた後、ウェーハをチップ状に分離して、図4に示すような構造のレーザ素子としたところ、室温において連続発振を示し、同じく410nmのレーザ光が第2の窒化物半導体層3側から観測された。なおn電極28を形成する際に、電極接触面のオーミックコンタクトを良くするために、イオンインプラントレーション等の技術を用いて、第2の窒化物半導

【 0 0 4 2 】

【図面の簡単な説明】

【図 2】 実施例 1 の発光素子の構造を示す模式断面図。

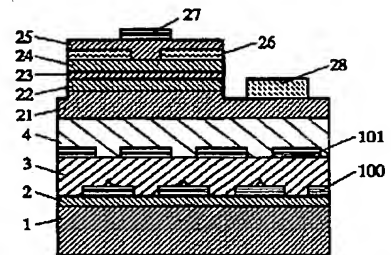
【図 3】 実施例 2 の発光素子の構造を示す模式断面図。

【符号の説明】

- 1・・・異種基板
- 2・・・第1の窒化物半導体層
- 3・・・第2の窒化物半導体層
- 4・・・第3の窒化物半導体層
- 11, 21・・・n側コンタクト層
- 12, 22・・・n側クラッド層
- 13, 23・・・活性層
- 14, 24・・・p側クラッド層
- 15, 25・・・p側コンタクト層
- 20・・・クラック防止層
- 26・・・電流阻止層
- 16, 27・・・p電極
- 17・・・pパッド電極
- 18, 28・・・n電極
- 100・・・第1の反射鏡
- 101・・・第2の反射鏡

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【圖 3】



【図 4】

